

Species Report of *Ranunculus hawaiiensis* (makou)
Version 1.0



Ranunculus hawaiiensis. Photo by G.D. Carr

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Ranunculus hawaiiensis Species Report, Final Draft

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EXECUTIVE SUMMARY

This document presents the Species Report for *Ranunculus hawaiiensis* (makou) to analyze the overall viability of the species. To assess viability, we used the three conservation biology principles of resiliency, representation, and redundancy. We identified the species' ecological requirements for survival and reproduction at the individual, population, and species levels, and described risk factors influencing the species' current condition.

Ranunculus hawaiiensis is a member of the buttercup family, Ranunculaceae. *Ranunculus hawaiiensis* is endemic to both Maui and Hawai'i and typically found in mesic forest on grassy slopes and scree, and in open pastures, at 6,000 to 6,700 feet (1,800 to 2,000 meters [m]), in the montane mesic (Hawai'i), montane dry (Hawai'i), and subalpine (Hawai'i and Maui) ecosystems (Pratt et al. 2007, p. 161; Duncan 1999, p. 1088; HBMP 2010). Historically, *R. hawaiiensis* was wide-ranging on the island of Hawai'i. Joseph F. Rock described *R. hawaiiensis* as "not uncommon on Pu'unianiau crater and exceedingly plentiful on Mauna Kea, especially above Waiki'i and the craters Kaluamakani and Moano" (Rock 1913, p. 82). In the 1980s and 1990s, this species numbered several hundred individuals on both Maui and Hawai'i (USFWS 2016, p. 67,804). On Maui, a few individuals were observed on a cliff in 1994; however, this occurrence was not relocated in further surveys (PEPP 2013, p. 177). In total 22 population units (19 on Hawai'i and three on Maui) were known (HBMP 2010). Currently, there are no known wild individuals, but more surveys are needed (Weisenberger pers. comm. 2020).

The main threats to *Ranunculus hawaiiensis* are habitat degradation and destruction and predation by feral ungulates (i.e., pigs (*Sus scrofa*), wild cattle (*Bos taurus*), and mouflon sheep (*Ovis orientalis orientalis*)), habitat degradation and destruction by and competition with invasive nonnative plants, stochastic events such as drought and erosion, wildfires, consequences of small population sizes, climate change, and inadequate regulatory mechanisms.

We define resiliency as the capacity of a population (or a species) to withstand stochastic disturbance events. We can measure resiliency for *Ranunculus hawaiiensis* based on the metric of population size. Redundancy is defined as the ability of a species to withstand catastrophic events. We evaluated redundancy for *R. hawaiiensis* based on the metrics of the number of populations, resilience of populations, and the distribution of the species across its range. Representation is defined as genetic and ecological diversity secured throughout multiple populations across the range of the species. We can measure representation based on the genetic diversity and habitat variation within and among multiple and resilient populations.

Currently, no known individuals of *Ranunculus hawaiiensis* exist in the wild. Seeds representing founders from Kapāpla, Hakalau, Mauna Kea, and Maui are stored at Lyon Arboretum and Hakalau National Wildlife Refuge. There are three plants at the Volcano Rare Plant Facility greenhouse. In the current condition, the overall viability of this species is extremely low, as we evaluated resiliency, redundancy, and representation as extremely low.

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INTRODUCTION

Ranunculus hawaiiensis, also known as makou, is one of two native Hawaiian species in the buttercup family (Ranunculaceae) (Duncan 1999, p. 1,088). They are small, erect, perennial herbs which are endemic to the islands of Maui and Hawai‘i. They occur in mesic forests on grassy slopes and scree (a mass of small loose stones that form or cover a slope on a mountain), in open pastures and in the montane mesic, montane dry, and subalpine ecosystems (Pratt et al. 2007, p. 161; Duncan 1999, p. 1,088; HBMP 2010).

Species Report Overview

This Species Report summarizes the biology and current status of *Ranunculus hawaiiensis* and was conducted by Pacific Islands Fish and Wildlife Office. It is a biological report that provides an in-depth review of the species’ biology, factors influencing viability (threats and conservation actions), and an evaluation of its current status and viability.

The intent is for the Species Report to be easily updated as new information becomes available, and to support the functions of the Service’s Endangered Species Program. As such, the Species Report will be a living document and biological foundation for other documents such as recovery plans, status in biological opinions, and 5-year reviews.

Regulatory History

Ranunculus hawaiiensis was listed as an endangered species on September 30, 2016 (81 FR 67786, U.S. Fish and Wildlife Service [USFWS] 2016). No critical habitat has been designated for this species. A recovery outline was completed on July 30, 2020 and a recovery plan is currently in preparation (USFWS 2020a).

Methodology

We used the best scientific available to us, including peer-reviewed literature, grey literature (government and academic reports), and expert elicitation.

To assess the current status and viability of *Ranunculus hawaiiensis*, we identified population units. The classic definition of a population is a self-reproducing group of conspecific individuals that occupies a defined area over a span of evolutionary time, an assemblage of genes (the gene pool) of its own, and has its own ecological niche. However, due to information gaps, we could not assess the viability of *R. hawaiiensis* using this definition. The Hawaii and Pacific Plants Recovery Coordinating Committee revised its recovery objectives guidelines in 2011 and included a working definition of a population for plants: “a group of conspecific individuals that are in close spatial proximity to each other (i.e., less than 1,000 meters apart), and are presumed to be genetically similar and capable of sexual (recombinant) reproduction” (HPPRCC 2011, p. 1).

Based on this working definition, maps were created to display population units. In an effort to protect the sensitivity of species data, we created maps with symbol markers rather than displaying species points or polygons. We created the symbols in steps. First, we added a 500-meter buffer around each individual species point and polygon. We then dissolved all buffer areas intersecting each other into a single shape. Next, we created a centroid (i.e., point

representing the center of a polygon) within each dissolved buffer area. The symbol marker represents the centroid. Finally, the Disperse Marker tool in ArcGIS Pro was used shift symbol markers that were overlapping so they would all be visible at the scale of the map. All points and polygons were used in this process, regardless of observation date or current status (historical, current, extant, or extirpated), to represent the known range of the species.

Species Viability

The Species Report assesses the ability of *Ranunculus hawaiensis* to maintain viability over time. Viability is the ability or likelihood of the species to maintain populations over time, (i.e., likelihood of avoiding extinction). To assess the viability of *R. hawaiensis*, we used the three conservation biology principles of resiliency, redundancy, and representation, or the “3Rs” (Figure 1; USFWS 2016, entire). We will evaluate the viability of a species by describing what the species needs to be resilient, redundant, and represented, and compare that to the status of the species based on the most recent information available to us.

Definitions

Resiliency is the capacity of a population or a species to withstand the more extreme limits of normal year-to-year variation in environmental conditions such as temperature and rainfall extremes, and unpredictable but seasonally frequent perturbations such as fire, flooding, and storms (i.e., environmental stochasticity). Quantitative information on the resiliency of a population or species is often unavailable. However, in the most general sense, a population or species that can be found within a known area over an extended period of time (e.g., seasons or years) is likely to be resilient to current environmental stochasticity. If quantitative information is available, a resilient population or species will show enough reproduction and recruitment to maintain or increase the numbers of individuals in the population or species, and possibly expand the range of occupancy. Thus, resiliency is positively related to population size and growth rate, and may also influence the connectivity among populations.

Redundancy is having more than one resilient population distributed across the landscape, thereby minimizing the risk of extinction of the species. To be effective at achieving redundancy, the distribution of redundant populations across the geographic range should exceed the area of impact of a catastrophic event that would otherwise overwhelm the resilient capacity of the populations of a species. In the report, catastrophic events are distinguished from environmental stochasticity in that they are relatively unpredictable and infrequent events that exceed the more extreme limits of normal year-to-year variation in environmental conditions (i.e., environmental stochasticity and thus expose populations or species to an elevated extinction risk within the area of impact of the catastrophic event. Redundancy is conferred upon a species when the geographic range of the species exceeds the area of impact of any anticipated catastrophic event. In general, a wider range of habitat types, a greater geographic distribution, and connectivity across the geographic range will increase the redundancy of a species and its ability to survive a catastrophic event.

Representation is having more than one population of a species occupying the full range of habitat types used by the species. Alternatively, representation can be viewed as maintaining the breadth of genetic diversity within and among populations, in order to allow the species to adapt to changing environmental conditions over time. The diversity of habitat types, or the breadth of

the genetic diversity of a species, is strongly influenced by the current and historic biogeographical range of the species. Conserving this range should take into account historic latitudinal and longitudinal ranges, elevation gradients, climatic gradients, soil types, habitat types, seasonal condition, etc. Connectivity among populations and habitats is also an important consideration in evaluating representation.

The viability of a species is derived from the combined effects of the 3Rs. A species is considered viable when there are a sufficient number of self-sustaining populations (resiliency) distributed over a large enough area across the range of the species (redundancy) and occupying a range of habitats to maintain environmental and genetic diversity (representation) to allow the species to persist indefinitely when faced with annual environmental stochasticity and infrequent catastrophic events. Common ecological features are part of each of the 3Rs. This is especially true of connectivity among habitats across the range of the species. Connectivity sustains dispersal of individuals, which in turn greatly affects genetic diversity within and among populations. Connectivity also sustains access to the full range of habitats normally used by the species, and is essential for re-establishing occupancy of habitats following severe environmental stochasticity or catastrophic events (see Figure 1 for more examples of overlap among the 3Rs). Another way the three principles are inter-related is through the foundation of population resiliency. Resiliency is assessed at the population level, while redundancy and representation are assessed at the species level. Resilient populations are the necessary foundation needed to attain sustained or increasing representation and redundancy within the species. For example, a species cannot have high redundancy if the populations have low resiliency. The assessment of viability is not binary, in which a species is either viable or not, but rather on a continual scale of degrees of viability, from low to high. The health, number and distribution of populations were analyzed to determine the 3Rs and viability. In broad terms, the more resilient, represented, and redundant a species is, the more viable the species is. The current understanding of factors, including threats and conservation actions, will influence how the 3Rs and viability are interpreted for *Ranunculus hawaiiensis*.

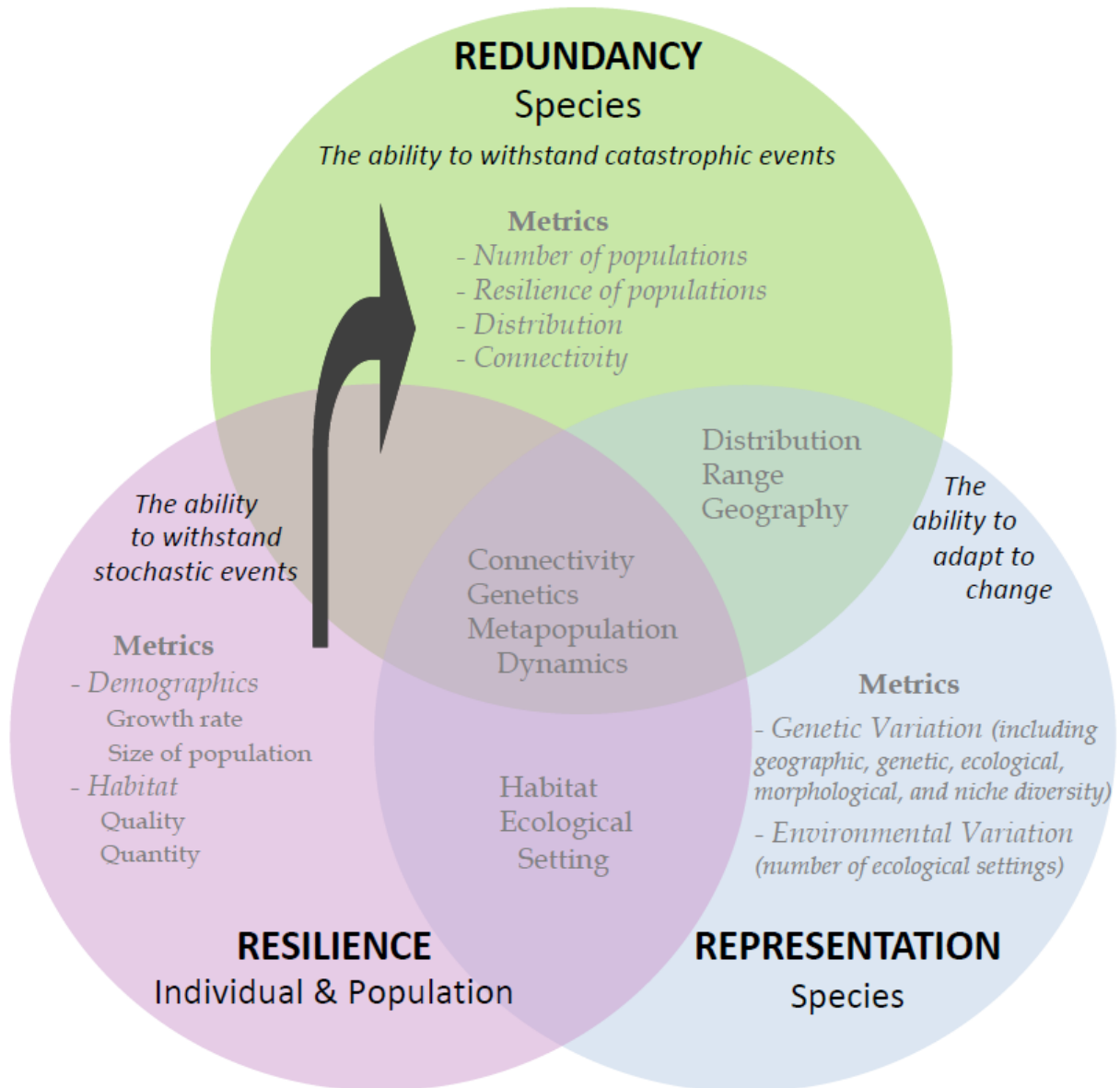


Figure 1. The three conservation biology principles of resiliency, redundancy, and representation, or the “3Rs”.

SPECIES ECOLOGY

Species Description

Ranunculus hawaiiensis was first described by A. Gray (1854) from a type specimen collected on the island of Hawai‘i during the South Pacific Exploring Expedition under Commander Wilkes (Mann 1866, p. 143). *Ranunculus hawaiiensis* is endemic to both the islands of Maui and Hawai‘i and typical habitat is mesic forest on grassy slopes and scree, and in open pastures, at 6,000 to 6,700 ft (1,800 to 2,000 m), in the montane mesic (Hawai‘i), montane dry (Hawai‘i), and subalpine (Hawai‘i and Maui) forest and shrubland ecosystems (Pratt et al. 2007, p. 161; Duncan 1999, p. 1,088; HBMP 2010).

Ranunculus hawaiiensis belongs to the buttercup family, Ranunculaceae. The buttercup family consists of 40 to 50 genera and 1,500 to 2,000 species of terrestrial or sometimes aquatic herbs, and occasionally vines or shrubs which are native to primarily temperate regions of the Northern and Southern Hemisphere. They are also known to occur in tropical montane regions (Duncan 1999, p. 1,087).

Ranunculus hawaiiensis is an erect or ascending perennial herb with fibrous roots. Stems are densely covered with golden or whitish hairs. Basal leaves (leaves that grow at the lowest part of the stem) are twice compound, with leaflets lanceolate (narrow oval shape tapering to a point at each end) with the terminal one largest and irregularly toothed and lobed. The small five-petaled, yellow, glossy flowers are numerous in branched open cymes (a flower cluster with a central stem bearing a single terminal flower that develops first, the other flowers in the cluster developing as terminal buds of lateral stems), and contain a scale-covered nectary at the base. Achenes (dry, one-seeded fruits) are numerous in an ovoid head and are margined with a narrow wing. *Ranunculus hawaiiensis* differs from *Ranunculus mauiensis* with respect to the degree to which achenes are beaked and the length of the achene body. *Ranunculus mauiensis* are 0.08 to 0.09 inches (in) (2 to 2.2 millimeters [mm]) long whereas *R. hawaiiensis* achenes are about 0.2 in (5 mm) long. On the slopes of Haleakalā on Maui, both species of *Ranunculus* share similar characteristics and intergradation is known to occur, further study of these populations is needed (Duncan. 1999, p. 1,088).

Both the original colonist of and current species, *Ranunculus hawaiiensis*, have a monomorphic breeding system; they are hermaphrodites. The presumed pollinators are insects, due to the presumed pollinator of the colonist and the color and morphology of the flower. Reproduction of *R. hawaiiensis* occurs by seeds that drop near the parent plant. Seed-eating birds may be a potential dispersal vector, and seeds could be potentially carried in mud on the feet of birds (Sakai et al. 1995, p. 2,527; Carlquist 1966, pp. 314, 326).

Ranunculus hawaiiensis individuals flower in the summer months and fruit was observed from September to November (BISH 2020), see Table 1, below. *Ranunculus hawaiiensis* plants have been observed to go dormant, or possibly dead, in the months of January and May. More observations are needed to describe the possibility of dormancy (PEPP pers. comm., 2019).

Table 1. Flowering and fruiting period for *Ranunculus hawaiiensis*.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Flower						x	x					
Seeds								x	x	x	x	

The National Tropical Botanical Garden and Hawai‘i Volcanoes National Park have successfully propagated *R. hawaiiensis* by seeds and cuttings since 2002 (NTBG 2002 and HAVO 2003). Germination of viable seeds takes one to six months, seedlings should be kept in a shaded area until they are ready for outplanting, then they should be moved to full sun to harden off before planting (Lilleeng-Rosenberger 2005, p. 313).

Individual Needs

The chromosome numbers for *Ranunculus hawaiiensis* are $2n = 28$ (Wagner et al. 1999).

The life stages (seed, seedlings, vegetative, and flowering plants) of *Ranunculus hawaiiensis* require similar habitat resources. It is suspected that *R. hawaiiensis* also experiences dormancy. Dormancy is a species adaptation to surviving in harsh climates such as periods of high or low temperatures and drought. During dormancy, the plants do not exhibit any visible external growth. They become metabolically inactive in order to survive harsh conditions when growth isn't possible (Kamenetsky 2009, p. 2,004). Average temperature for sites in which *R. hawaiiensis* is found is 52.3 °F (11.3 °C), and temperature ranges from a low of 42.8 °F (9.6 °C) to a high of 59.2 °F (15.1 °C). Average annual precipitation is 56 in (1,435 mm), and precipitation ranges from 18 in (449 mm) to 208 in (5,293 mm) (USFWS 2020, unpublished data).

Ranunculus hawaiiensis is found in several habitat types, including montane wet, dry and mesic forests as well as in montane-subalpine mesic and dry shrublands and grasslands. *Ranunculus hawaiiensis* can also be found on barren lava and scree. The substrate conditions found within the montane-subalpine dry forest range from cinder, well-drained, loam soils derived from volcanic ash, and weathered 'a'a or pahoehoe basaltic lava with little soil development (Gagne and Cuddihy 1999, p. 110). Montane dry grasslands have either a sandy loam soil or less developed cindery soil (Gagne and Cuddihy 1999, p. 107). Montane-subalpine dry shrublands occur on sandy-loamy soils derived from volcanic ash or sand, or weathered lava (Gagne and Cuddihy 1999, p. 107). Geological substrates are highly variable for montane-subalpine mesic grasslands and shrublands, but soils are generally shallow and often dry out regularly and may contain many rock outcrops. The soils of subalpine mesic shrublands are much rockier than those of the subalpine mesic grasslands (Gagne and Cuddihy 1999, p. 111). Mesic forest substrates are highly variable but are generally well-drained and include rocky, shallow, organic muck soils, steep rocky talus soils, shallow soils over weathered rock in steep gulches, and deep soils over soft weathered rock and gravelly alluvium (soils composed of clay, silt, sand, and gravel) (Gagne and Cuddihy 1999, p. 111). Substrates for Hawai'i wet forest vary from very weathered soils on older islands to rocky substrates on recent lava flows on younger islands. Soils vary throughout the island chain, from gray acidic clays on older islands to thin organic mucks over lava flows and ash beds on Hawai'i (Clark et al. 2020, p. 2). At the seed stage, the seeds fall from the achene that is located on the mother plant, and are deposited onto soil or other substrates provide for the habitats the species occurs in.

Table 2 below summarizes other physical characteristics (elevation, temperature, precipitation, and habitat type) for each population unit. Associated native plant species include: *Metrosideros polymorpha* ('ōhi'a), *Myoporum sandwicense* (naio), *Leptecophylla tameiameiae* (pūkiawe), *Vaccinium reticulatum* ('ōhelo), *Dodonaea viscosa* (a'ali'i), *Acacia koa* (koa) *Coprosma montana* (pilo), *Dubautia ciliolata* (na'ena'e), *Deschampsia nubigena* (hairgrass), *Tetramalopium humile* (no common name), and *Cheirodendron* spp. ('olapa) (HBMP 2010). If all of the resource needs are met for this individual, than the species is highly resilient.

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Table 2. Physical characteristics (elevation, temperature, precipitation and habitat types) of environment within population units of *Ranunculus hawaiiensis* (USFWS 2020, unpublished data).

Population Unit	Elevation	Temperature	Precipitation	Habitat Type
A	6,518 ft (1,986 m)	52.3°F (11.3 °C)	77 in (1,959 mm)	Montane Mesic Forest
B	5,384 ft (1,641 m)	56.1 °F (13.4 °C)	91 in (2,308 mm)	Montane Mesic Forest
B	4,938 ft (1,505 m)	57.6 °F (14.2 °C)	89 in (2,253 mm)	Montane Mesic Forest
B	5,324 ft (1,623 m)	55.9 °F (13.3 °C)	88 in (2,243 mm)	Montane Wet Forest
B	6,230 ft (1,899 m)	53.4 °F (11.9 °C)	77 in (1,954 mm)	Montane Mesic Forest
C	5,925 ft (1,806 m)	54.7 °F (12.6 °C)	29 in (730 mm)	Montane Mesic Forest
D	6,001 ft (1,829 m)	53.6 °F (12.0 °C)	85 in (2169 mm)	Montane Mesic Shrubland and Grassland
D	6,106 ft (1,861 m)	53.2 °F (11.8 °C)	84 in (2,122 mm)	Montane Mesic Forest
E	4,603 ft (1,403 m)	59.2 °F (15.1 °C)	33 in (833 mm)	Montane Mesic Forest
F	6,194 ft (1,888 m)	52.9 °F (11.6 °C)	79 in (2,006 mm)	Barren Lava Flow
G	6,476 ft (1,974 m)	52.2 °F (11.2 °C)	66 in (1,684 mm)	Montane Mesic Shrubland and Grassland
H	6,634 ft (2,022 m)	51.6 °F (10.9 °C)	56 in (1,431 mm)	Montane Mesic Shrubland and Grassland
H	6,640 ft (2,024 m)	51.6 °F (10.9 °C)	55 in (1,390 mm)	Montane Mesic Shrubland and Grassland
I	8,110 ft (2,472 m)	42.8 °F (9.6 °C)	26 in (661 mm)	Montane Dry Shrubland and Grassland
J	6,493 ft (1,979 m)	52.3 °F (11.3 °C)	47 in (1,194 mm)	Montane Mesic Shrubland and Grassland
J	6,480 ft (1,975 m)	52.3 °F (11.3 °C)	48 in (1,223 mm)	Montane Mesic Forest
K	8,724 ft (2,659 m)	48 °F (8.9 °C)	30 in (773 mm)	Montane Dry Shrubland and Grassland
L	9,593 ft (2,924 m)	46.2 °F (7.9 °C)	35 in (880 mm)	Barren Lava Flow

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M	4,364 ft (1,330 m)	57.7 °F (14.3 °C)	208 in (5,293 mm)	Montane Wet Forest
N	8,287 ft (2,526 m)	48.7 °F (9.3 °C)	18 in (449 mm)	Montane Dry Forest
O	8,353 ft (2,546 m)	48.2 °F (9.0 °C)	36 in (902 mm)	Montane Dry Shrubland and Grassland
O	8,360 ft (2,548 m)	48.2 °F (9.0 °C)	33 in (841 mm)	Montane Dry Shrubland and Grassland
P	4,780 ft (1,463 m)	58.8 °F (14.9 °C)	24 in (614 mm)	Montane Dry Shrubland and Grassland
Q	7,402 ft (2,256 m)	50.2 °F (10.1 °C)	27 in (677 mm)	Montane Dry Shrubland and Grassland
R	6,844 ft (2,086 m)	51.8 °F (11 °C)	27 in (677 mm)	Montane Dry Shrubland and Grassland
S	5,994 ft (1,827 m)	54.7 °F (12.6 °C)	27 in (688 mm)	Montane Dry Shrubland and Grassland
T	7,005 ft (2,135 m)	50.4 °F (10.2 °C)	54 in (1,363 mm)	Barren Lava Flow
U	6,834 ft (2,083 m)	50.7 °F (10.4 °C)	53 in (1,345 mm)	Barren Lava Flow
V	6,844 ft (2,086 m)	50.7 °F (10.4 °C)	58 in (1,471 mm)	Montane Mesic Shrubland and Grassland

Population Needs

Based on historic and current observations we assume that the population structure of *Ranunculus hawaiiensis* consists of plants in all life stages, including seedlings, immature, and mature, reproductive plants. A healthy population consists of abundant individuals within habitat patches of adequate area and quality to maintain survival and reproduction in spite of disturbance.

Habitats supply the basic needs (nutrients, air, water, space to grow, and shelter) of populations. Populations of *Ranunculus hawaiiensis* occur in variety of habitats on Maui and Hawai‘i. These habitats provide a diversity of environmental conditions for populations. The range of habitats may act as a buffer against changes in climatic variables such as precipitation and temperature. When populations occur in different habitat types, islands, and locations, it is unlikely that all populations will experience the same changes in environmental conditions, thus ensuring that not all populations will fail due to unfavorable conditions.

There are currently no known extant wild populations of *Ranunculus hawaiiensis*, but more surveys of historic populations are needed. Populations of *R. hawaiiensis* historically occurred on barren lava flows on Mauna Kea at Pu‘u Kōle on Hawai‘i and at Kahikinui and Ko‘olau Gap on Maui. Populations occurred in the dry forests of Mauna Kea’s South Slope and the dry

shrublands and grasslands of Hualālai, Mauna Kea's East, South, and, North Slopes, Waiki'i and Upper Pā'auhau of Hawai'i island. *Ranunculus hawaiiensis* occurred in the mesic forests of Kahuku East, Kapāpala, Keālia, Keahou, Kahalu'u and 'Āinahou of Hawai'i. Suitable habitats also included the mesic shrublands and grasslands of Keauhou, 'Āinahou on Hawai'i and at Waikamoi Gulch on Maui. Suitable habitat was also known from the wet forests of Kapāpala and Hakalau Nui on Hawai'i. Lastly, populations occurred in subalpine zones around Mauna Kea, Mauna Loa and Hualālai on Hawai'i and Haleakalā on Maui.

The dispersal ability and capacity for genetic exchange among these populations of *Ranunculus hawaiiensis* is unknown. *Ranunculus hawaiiensis* are hermaphroditic and pollinated by insects (Sakai et al. 1995, p. 2,527). Pollinators are likely essential to maintaining outcrossing levels and genetic diversity.

Habitats can be negatively impacted by threats, such as invasive species. Competition with other species (including native plants) and/or nonnative invasive species, along with the additional threats that are described below in Factors Influencing Viability, can limit seedlings, vegetative plants, and flowering plants from getting water, soil, and sunlight that they need. Populations of *Ranunculus hawaiiensis* need habitats in which the degree of threats are at a low enough level that the habitat is able to continue to be suitable and supply the basic needs of the *R. hawaiiensis* populations. Resiliency is the capacity of a population (or a species) to withstand stochastic disturbance events, however the survival rate of *R. hawaiiensis* seedlings and growth rate needed to sustain populations in the presence of threats is unknown. There are no known individuals or populations left in the wild, thus, we measure resiliency of wild and reintroduced populations by population size and habitat quality.

Species Needs

Species need resilient populations that are redundant and represented.

Redundancy is the ability of *Ranunculus hawaiiensis* to withstand catastrophic events and is measured by the number of populations (redundancy/duplication), their resiliency, and their distribution across the species' range, as well as their proximity to one another. In order to achieve redundancy, the distribution of *R. hawaiiensis* populations across the geographic range should exceed the area of impact of a catastrophic event that would otherwise overwhelm the resilient capacity of the populations. Essentially, the more populations of *R. hawaiiensis*, the more resilient those populations are, and the broader the distribution of those populations, the more redundancy the species will exhibit, thereby increasing its ability to survive a catastrophic event. *Ranunculus hawaiiensis* has been in cultivation since 2002 (NTBG 2002; VRPF 2002) and is currently in cultivation at Hakalau National Wildlife Refuge, Lyon Arboretum, and the Volcano Rare Plant Facility (Hakalau NWR 2019, p. 9; Lyon Arboretum 2020; VRPF 2019). Efforts are underway to reintroduce this species in its former range at Hakalau National Wildlife Refuge (2019). For *R. hawaiiensis*, redundancy requires the presence of multiple, stable to increasing populations distributed across a large enough range on Maui and Hawai'i to prevent species extinctions due to catastrophic events.

Representation is the ability of *Ranunculus hawaiiensis* to adapt to changing environmental conditions over time and can be measured by having more than one resilient population

occupying the full range of suitable habitat used by the species. Alternatively, representation can be viewed as maintaining the breadth of genetic diversity within and among populations, in order to allow the species to adapt to changing environmental conditions over time. Unique traits likely exist in populations in different habitat types and by island. We measure representation by the number of populations within each habitat type and island. Given the diversity of habitats that *R. hawaiiensis* occupied, it was likely more wide spread historically. We have no historical genetic information, however, we can assume that as populations decline and disappear, genetic diversity decreases. We have limited information on the connectivity of populations which would support genetic exchange and representation. However, connectivity decreases with habitat loss and fragmentation, thus we can assume that genetic diversity has likely decreased in the species over time. Representation is maintained in *R. hawaiiensis* by having abundant individuals in stable to increasing populations that represent the existing full genetic diversity dispersed throughout its full range of habitat types on Maui and Hawai'i. We can measure representation by how adequately the *ex situ* collections represent populations, as well as how many resilient populations represent each identified habitat type, as a proxy for how well the genetic structure of *R. hawaiiensis* is secured.

FACTORS INFLUENCING VIABILITY

Threats

Threats to *Ranunculus hawaiiensis* include habitat degradation and destruction by feral ungulates including pigs (*Sus scrofa*), wild cattle (*Bos taurus*), and mouflon sheep (*Ovis orientalis orientalis*). Feral ungulates reduce the suitability of habitat for individuals to persist and constricts area for population to occupy by destroying vegetative cover, soil disturbance, dispersal of invasive plant seeds on hooves and coats, and through the spread of seeds in feces; and creation of open disturbed areas conducive to further invasion by invasive plant species. All of these impacts can lead to the subsequent conversion of a native plant community to one dominated by invasive species. These ungulates also trample and forage on *R. hawaiiensis* which directly kills individuals (USFWS 2016, p. 67,805).

Nonnative invasive plants, such as *Ehrharta stipoides* (meadow ricegrass), *Holcus lanatus* (common velvetgrass), and various other grasses, modify and destroy native habitat, outcompete native plants, and have been reported in areas where *R. hawaiiensis* occurs (HBMP 2010). Habitat modification by invasive plant species has the potential to reduce pollination services which can in turn potentially reduce reproductive success. Nonnative plant introductions increase competition with invasive plants which restricts resources an individual needs to survive.

Drought and erosion pose a threat in the areas of the last known occurrences of *Ranunculus hawaiiensis* on Maui (PEPP 2013, p. 177). Drought reduces water availability to individuals which causes stress and poor condition in individuals. Erosion may cause soil and or rocks to fall on individuals or a landslide which can eliminate a population. It is unknown where either of these are also threats to populations on Hawai'i.

Wildfire poses a threat to *Ranunculus hawaiiensis* and the habitats it needs to survive. Wildfires leave the landscape bare and vulnerable to erosion and nonnative weed invasions. Invasive weeds, particularly fountain grass (*Cenchrus setaceus*), which is a fire-adapted weed that has

evolved to rely on fire for regeneration, are quick to reclaim burned areas, further changing the natural fire dynamics. The presence of such species in Hawaiian ecosystems greatly increases the intensity, extent, and frequency of fire, especially during drier months or drought (TMA 2017, p. 16).

Ranunculus hawaiiensis has limited adaptability to environmental changes since there are no individuals left in the wild. This species experiences reduced reproductive vigor due to low levels of genetic variability, thereby lessening the probability of long-term persistence (USFWS 2016, p. 67,805).

Climate change may pose a threat to this species. Fortini et al. (2013) conducted a landscape-based assessment of climate change vulnerability for native plants of Hawai‘i using high resolution climate change projections. Climate change vulnerability is defined as the relative inability of a species to display the possible responses necessary for persistence under climate change. The assessment by Fortini et al. (2013, p. 87) concluded that *Ranunculus hawaiiensis* is vulnerable to the impacts of climate change, with a vulnerability score of 0.232 (on a scale of 0 being not vulnerable to 1 being extremely vulnerable to climate change). Therefore, additional management actions may be needed to conserve this taxon into the future, such as locating key microsites that overlap with current and future climate envelopes for outplanting effort.

Inadequate regulatory mechanisms threaten *Ranunculus hawaiiensis*. Nonnative feral ungulates pose threat to *R. hawaiiensis* through destruction and degradation of the species’ habitat and herbivory but regulatory mechanisms are inadequate to address this threat (USFWS 2016). The State of Hawai‘i provides game mammal (feral pigs and mouflon sheep) hunting opportunities on 38 State-designated public hunting areas on the island of Hawai‘i and six public hunting units on the island of Maui (HDLNR 2015, pp. 19–21, 66–77). However, the State’s management objectives for game animals range from maximizing public hunting opportunities (e.g., “sustained yield”) in some areas to removal by State staff, or their designees, in other areas (HDLNR 2015, entire).

Introduction of Nonnative Plants and Insects: Currently, four agencies are responsible for inspection of goods arriving in Hawai‘i (USFWS 2016, p. 67,843). The Hawai‘i Department of Agriculture (HDOA) inspects domestic cargo and vessels and focuses on pests of concern to Hawai‘i, especially insects or plant diseases. The U.S. Department of Homeland Security-Customs and Border Protection (CBP) is responsible for inspecting commercial, private, and military vessels and aircraft and related cargo and passengers arriving from foreign locations (USFWS 2016, p. 67,844). The U.S. Department of Agriculture-Animal and Plant Health Inspection Service-Plant Protection and Quarantine (USDA-APHIS-PPQ) inspects propagative plant material, provides identification services for arriving plants and pests, and conducts pest risk assessments among other activities (HDOA 2009, p. 1). The Service inspects arriving wildlife products, enforces the injurious wildlife provisions of the Lacey Act (18 U.S.C. 42; 16 U.S.C. 3371 *et seq.*), and prosecutes CITES (Convention on International Trade in Wild Fauna and Flora) violations. The State of Hawai‘i allows the importation of most plant taxa, with limited exceptions (USFWS 2016, p. 67,845). It is likely that the introduction of most nonnative invertebrate pests to the State has been and continues to be accidental and incidental to other intentional and permitted activities. Many invasive weeds established on Hawai‘i have currently

limited but expanding ranges. Resources available to reduce the spread of these species and counter their negative ecological effects are limited. Control of established pests is largely focused on a few invasive species that cause significant economic or environmental damage to public and private lands, and comprehensive control of an array of invasive pests remains limited in scope (USFWS 2016, p. 67,845).

Conservation Actions

Ranunculus hawaiiensis has been in propagation since 2002 by the Volcano Rare Plant Facility and they have propagated plants from seed collections made from Hakalau, Ka‘u, Kahuku, and Mauna Kea. There are currently three plants in the greenhouse (VRPF 2003; 2019). The University of Hawai‘i’s Lyon Arboretum on O‘ahu has also been an *ex situ* repository for *R. hawaiiensis*, for both propagule storage and research on protocol development for propagule storage. They have one collection from Mauna Kea (Hawai‘i). Initial germination was 64 percent, and seeds took a couple months to start to germinate and continued to germinate for almost three years, indicating that seeds do not germinate quickly. It is currently unknown how long seeds can be stored until viability begins to decline. There are currently 25 seeds from this collection remaining in storage (Lyon Arboretum 2019).

Hawai‘i Volcanoes National Park discovered eight plants during the Kahuku vegetation survey in 2008. In 2009 only a single plant remained and the decision was made to transfer the plant to the Volcano Rare Plant Facility. However, likely due to high vog levels at the nursery at that time, the plant died. Seedlings were propagated from a nearby source outside of the park near the Kapapala/Ka‘ū forest boundary. In March 2011, 80 seedlings were planted in the Silversword 2 exclosure. Survival was low seven months following planting with 24 percent alive, none had survived past two years. Thirty seedlings were also planted at the Kahuku CCC exclosure. Growth was vigorous but only 37 percent survived two years post planting. Many of these individuals flowered and produced seeds prior to dying. Only 7 percent remained alive by three years post planting and none persisted for four years (2016). No recruitment has been observed but monitoring will continue. No known wild or planted individuals are known to be extant (HAVO 2019, pp. 25–26).

Hakalau National Wildlife Refuge has been propagating and outplanting *Ranunculus hawaiiensis* prior to its listing as endangered in 2016. The founders for the outplants are from Hakalau and Kanakaleonui (Mauna Kea) (Weisenberger pers. comm. 2020). Hakalau continues to maintain an *ex situ* collection in their nursery, as well as conduct reintroductions. They have reintroduced 562 individuals to date, and plants and seeds remain in their *ex situ* facilities for propagation (Hakalau NWR 2019, pp. 8–9).

Conservation actions, including weed control, fire management, ungulate fencing and removal, and reforestation, are being implemented by several watershed partnerships in species range of *Ranunculus hawaiiensis*. Watershed partnerships are organizations which work collaboratively with public and private partners to protect vital forested watershed lands (Hawai‘i Association of Watershed Partnerships (HAWP) 2020). The Three Mountain Alliance (TMA) watershed partnership implements conservation actions at Kahuku, Kapāpala, Keahou, ‘Āinahou, and Hualālai (TMA 2017, entire). The Mauna Kea Watershed Alliance is working to restore native ecosystems on Mauna Kea, Hakalau Nui, Waiki‘i and Upper Pā‘auhau. On Maui, the East Maui

Watershed Partnership works with The Nature Conservancy to preserve subalpine mesic habitats at Waikamoi Preserve (TNCH 2011, p. 13).

Regulatory actions such as the Endangered Species Act provide conservation benefits for *Ranunculus hawaiiensis*. The Service determined endangered status under the Endangered Species Act of 1973 (Act), as amended, for 39 plants and 10 animals on October 31, 2016 including *R. hawaiiensis* (USFWS 2016). The primary purpose of the Act is the conservation of endangered and threatened species and the ecosystems upon which they depend. The ultimate goal of such conservation efforts is the recovery of these listed species, so that they no longer need the protective measures of the Act. Conservation measures provided to species listed as endangered or threatened under the Act include recognition of threatened or endangered status, recovery planning, requirements for Federal protection, and prohibitions against certain activities. The Act encourages cooperation with the States and requires that recovery actions be carried out for all listed species. The Act and its implementing regulations in addition set forth a series of general prohibitions and exceptions that apply to all endangered wildlife and plants. For plants listed as endangered, the Act prohibits the malicious damage or destruction on areas under Federal jurisdiction and the removal, cutting, digging up, or damaging or destroying of such plants in knowing violation of any State law or regulation, including State criminal trespass law. Certain exceptions to the prohibitions apply to agents of the Service and State conservation agencies. The Service may issue permits to carry out otherwise prohibited activities involving endangered or threatened wildlife and plant species under certain circumstances. With regard to endangered plants, a permit must be issued for scientific purposes or for the enhancement of propagation or survival. For federally listed species unauthorized collecting, handling, possessing, selling, delivering, carrying, or transporting, including import or export across State lines and international boundaries, except for properly documented antique specimens of these taxa at least 100 years old, as defined by section 10(h)(1) of the Act, is prohibited. Damaging or destroying any of the listed plants in addition is violation of the Hawai'i State law prohibiting the take of listed species. The State of Hawai'i's endangered species law (HRS, Section 195-D) is automatically invoked when a species is Federally listed, and provides supplemental protection, including prohibiting take of listed species and encouraging conservation by State government agencies. Currently, *R. hawaiiensis* is only known to be extant (out-planted individuals) on Federal lands.

CURRENT CONDITION

Historical Condition

Habitat Distribution & Trends

Historically, dry forests in Hawai'i covered large areas and were comprised of a wide range of species and diversity. In general, the pre-human dry forests in Hawai'i were comprised of 109 tree species in 29 families, with 90 percent of all species endemic, 10 percent indigenous, and 37 percent being single island endemics. The historical fire regime in Hawai'i was characterized by infrequent, low severity fires, as few natural ignition sources existed (Javar-Salas et al. 2020, p. 3). The current extent of native dry forest cover may be as low as 1 percent of the original cover and forty-five percent of the dry forest plant species in Hawai'i are at risk of endangerment (Pau et al. 2009, p. 3,173). The island of Hawai'i currently contains roughly 92,000 acres (ac) (37,231 hectares [ha]) and Maui contains approximately 35,087 ac (14,199 ha) of dry forest, however

these forests are largely composed of a mixture of native /nonnative vegetation (Javar-Salas et al. 2020, pp. 9–10).

Before the arrival of humans, the fire regime in montane dry shrublands and grasslands was characterized by infrequent, low severity fires, as few natural ignition sources existed. It is believed that prior to human colonization, fuel was sparse in dry plant communities and most native vegetation had a low flammability (Pea et al. 2020, p. 3).

Hawai‘i montane-subalpine mesic forest occurred on the montane and subalpine slopes of Kaua‘i, Maui, and Hawai‘i. Montane mesic forests occurred above the lowland wet forest, below montane wet forests, and leeward of montane wet forests. Dominant trees included koa and ‘ōhi‘a and the understory consisted of many native sedges, ferns, and shrubs. Large expanses of the koa/‘ōhi‘a montane mesic forest were converted to cattle ranches after logging of koa. Browsing by feral ungulates, fires, and clearing of land for commercial tree planting and harvest have increased the spread of invasive grasses and reduced the quality and extent of the mesic forests and (Lowe et al. 2020, pp. 7–8). This montane-subalpine mesic forest system still occurs on Kaua‘i, Maui and Hawai‘i. The island of Hawai‘i contains the majority of this subtype while the islands of Maui and Kaua‘i contain only a few thousand acres each (Lowe et al. 2020, p. 7).

Prior to human contact the mesic grasslands and shrublands occurred as inclusions within mesic forests. These grassland and shrubland communities extended from the lowlands to the subalpine regions and were found on both the leeward and windward sides of the main Hawaiian islands. Ecological changes to the community are primarily a result of introduced fire-adapted grasses and long term disturbance by browsing ungulates. The increased frequency of fire in the introduced perennial grasslands has led to the development of homogenous fire climax grass communities in some subalpine environments (Ball et al. 2020, pp. 3–8).

A clear picture of pre-human conditions in montane wet forests is complicated by the extreme disturbance the lowlands have suffered post human contact. However relatively intact high-elevation montane rainforest currently cover large expanses in the same locations as they did in pre-human times (Clark et al. 2020, p. 4).

Historic Trends of *Ranunculus hawaiiensis*

Ranunculus hawaiiensis was first described by A. Gray (1854) from a type specimen collected on Hawai‘i during the South Pacific Exploring Expedition under Commander Wilkes (Mann 1866, p. 143). *Ranunculus hawaiiensis* is endemic to both Maui and Hawai‘i and typical habitat is mesic forest on grassy slopes and scree, and in open pastures, at 6,000 to 6,700 ft (1,800 to 2,000 m), in the montane mesic, montane dry, and subalpine ecosystems (Pratt et al. 2007, p. 161), see Figure 2 below for the islands within the species’ range.

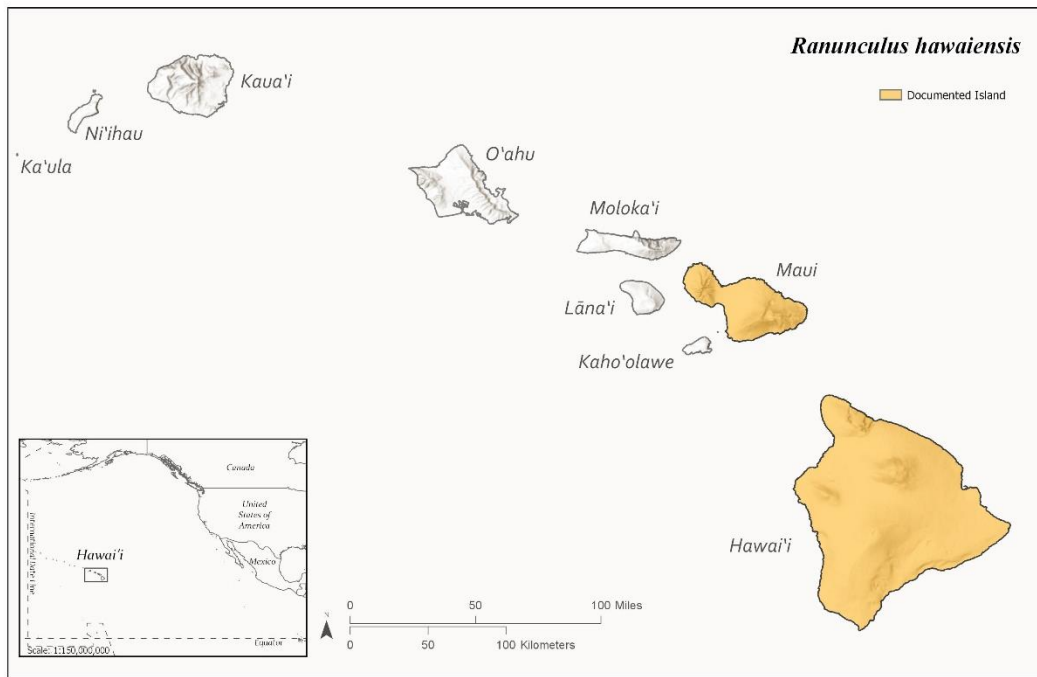


Figure 2. Historical range of *Ranunculus hawaiiensis*.

Historically, *Ranunculus hawaiiensis* was wide-ranging on the island of Hawai‘i. Joesph F. Rock described *R. hawaiiensis* as “not uncommon on Pu‘unianiau crater and exceedingly plentiful on Mauna Kea, especially above Waiki‘i and the craters Kaluamakani and Moano” (Rock 1913, p. 82). In 1927 it was relatively common in the scrub north of Holua Cave, while in 1959 no specimens were found in that general region except for two lone plants (HBMP 2010). In 1979, two large populations of 50 and 200 plants, were observed growing along skid trails in disturbed *Acacia-Metrosideros* forest with *Myoporum* (naio) understory. A smaller patch of about 30 plants occurred in disturbed mountain parkland (HBMP 2010). In the 1980s and 1990s, this species numbered several hundred individuals on both Maui and Hawai‘i (USFWS 2016, p. 67,804). On Maui, a few individuals were observed on a cliff in 1994; however, this occurrence was not relocated in further surveys (K. Fay, pers. comm. 2020). Additionally, no individuals were re-observed in Haleakalā National Park. In total 22 populations (19 on Hawai‘i and three on Maui) were known (HBMP 2010). Currently, there are no known wild individuals (PEPP pers. comm. 2020).

Current Condition

Although there are currently no known individuals of *Ranunculus hawaiiensis* in the wild, surveys during the times of year where recruitment is expected and dormancy is not, are needed to confirm any populaiton extirpations. Also, there is genetic representation of some populations in *ex situ* storage and in reintroductions. There are seeds in storage at Hakalau National Wildlife Refuge and Lyon Arboretum. There are also plants at the Volcano Rare Plant Facility. Hakalau reintroduced 562 individuals and have more propagules in storage for continued reintroduction efforts (Hakalau NWR 2019, pp. 8–9). Additional surveys for *R. hawaiiensis* in remaining

suitable habitat may lead to the discovery of new individuals. Figure 3 and Figure 4 depict the locations of the population units on Maui and Hawai‘i. Table 3 below includes information on the historic populations.

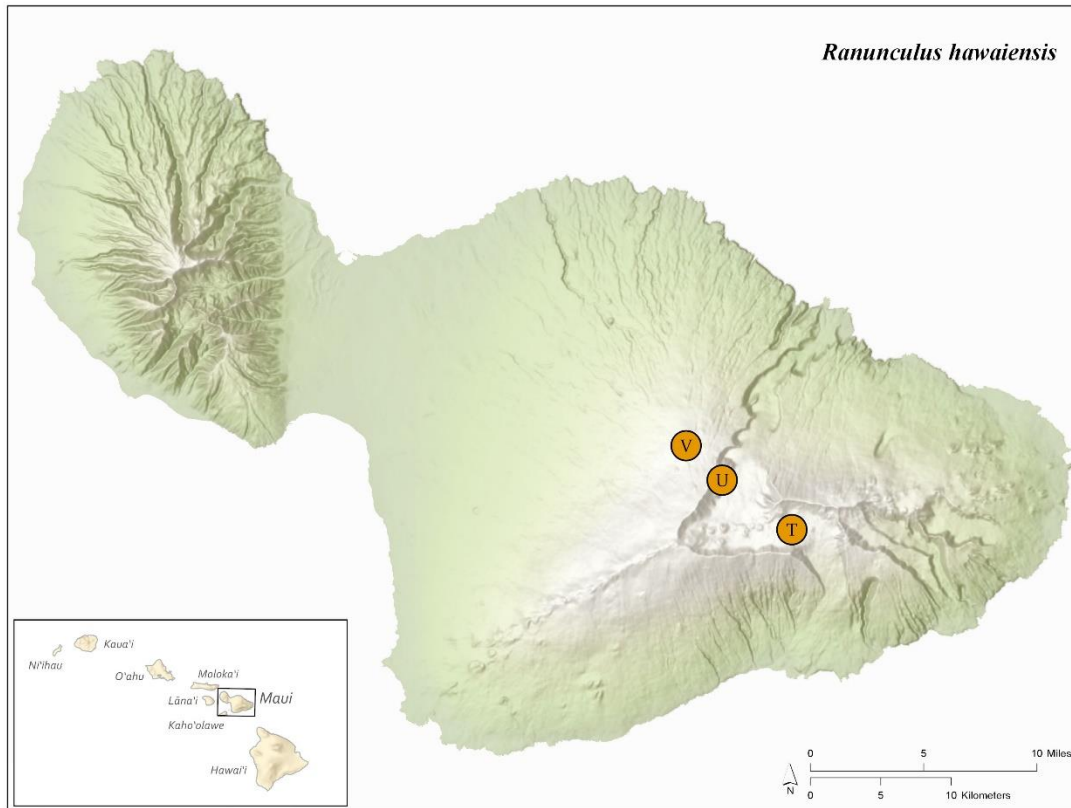


Figure 3. Distribution map of population units of *Ranunculus hawaiiensis* on Maui (USFWS 2020).

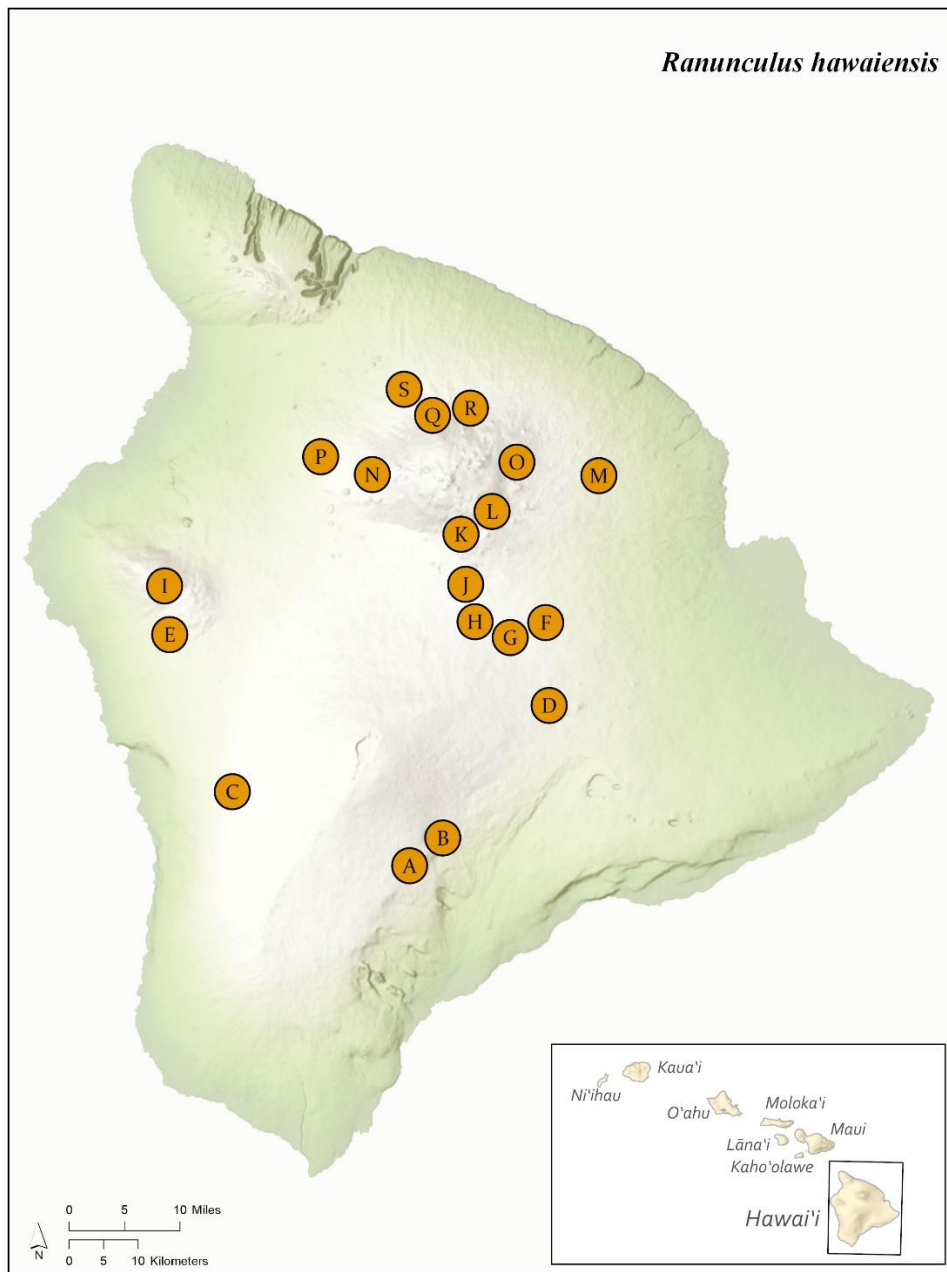


Figure 4. Distribution map of population units of *Ranunculus hawaiiensis* on Hawai'i (USFWS 2020)

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Table 3. Historic Populations Units of *Ranunculus hawaiiensis* (USFWS 2020).

Population Unit Name	Population Unit Letter	Habitat Type	Last Observation Date by Population Unit Name	Estimated Number of Individual
Hawai'i				
Kahuku	A	Montane Mesic Forest	1971	Unk
Kapāpala	B	Montane Mesic Forest and Montane Wet Forest	1991	28
Keālia	C	Montane Mesic Forest	1911	Unk
Keauhou	D	Montane Mesic Forest and Subalpine Mesic Shrublands and Grasslands	1983	280
Kahalu'u	E	Montane Mesic Forest	1911	Unk
‘Āinahou	F, G, H, J	Montane Mesic Forest and Sub alpine Mesic Shrublands and Grasslands	1979	36 (H)
Hualālai	I	Montane Dry Forest	1911	Unk
Mauna Kea South Slope	K, L, N	Montane Dry Forest and Subalpine Dry Shublands and Grasslands	1983	Unk
Hakalalu Nui	M	Montane Wet Forest	1991	Unk
Mauna Kea East Slope	N, O	Subalpine Dry Shublands and Grasslands	1991	1 (O)
Waiki'i	P	Subalpine Dry Shublands and Grasslands	1900	Unk
Mauna Kea North Slope	Q, R	Subalpine Dry Shublands and Grasslands	1909	Unk
Upper Pā'auhau	S	Subalpine Dry Shublands and Grasslands	1909	Unk
Maui				
Haleakalā-Kahikinui	T	Barren Lava Flow	1937	Unk
Ko'olau Gap	U	Barren Lava Flow	1959	Unk

Waikamoi Gulch	V	Subalpine Mesic Shrublands and Grasslands	1994	Unk
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SPECIES VIABILITY SUMMARY

Resiliency

For *Ranunculus hawaiiensis* to maintain viability, the population must be resilient. We determine resiliency for *R. hawaiiensis* based on the metrics of the number of individuals per population, and habitat quality. Currently there are no wild populations of *R. hawaiiensis*.

Population sizes have decreased over time and habitat extent and quality have also declined. Reintroductions have been conducted at Hakalau National Wildlife Refuge, however it is unknown if natural recruitment is occurring or the status of those reintroductions.

When evaluating the habitat quality to determine the species' resiliency, the following threats; habitat degradation and destruction by feral ungulates (i.e., pigs (*Sus scrofa*), wild cattle (*Bos taurus*), and mouflon sheep (*Ovis orientalis orientalis*)), habitat degradation and destruction by and competition with invasive nonnative plants, stochastic events such as drought and erosion, and wildfires, continue to degrade the suitable habitat for *Ranunculus hawaiiensis*.

Resiliency of the current population in the wild is extremely low, as no individuals are known to persist in the wild at the moment, but surveys during the times of year where the species is expected to be most abundant are needed to confirm population extirpations.

Redundancy

We evaluate redundancy for *Ranunculus hawaiiensis* based on the metric of the number of resilient populations and their distribution across the known range of the species. Redundancy for *R. hawaiiensis* in the wild is extremely low since there are no known wild populations.

Representation

We define representation for *Ranunculus hawaiiensis* based on the number of populations occupying the different habitat types used by *R. hawaiiensis*. As mentioned previously, there are no known wild individuals. There are seeds in storage at Hakalau National Wildlife Refuge and Lyon Arboretum from at least three different populations (Kapāpla, Hakalau, and Mauna Kea. There are also plants at the Volcano Rare Plant Facility and Hakalau National Wildlife Refuge greenhouses. Hakalau National Wildlife Refuge has outplanted several individuals over the years, however it is unknown if natural recruitment is occurring or the status of those reintroductions. With so few founders secured in *ex situ* or at a single reintroduction site of unknown status, representation is likely extremely low. However, these collections are promising as founders are secured in *ex situ* storage and the plants do well in cultivation. The species is cultivated in more than one *ex situ* facility, so a catastrophe at any facility would not drive the species to complete extinction.

Species Viability Summary

With no currently known populations in the wild, there is essentially no resiliency or redundancy within this species. Extremely low levels of representation exist by maintaining the *ex situ* population, however, the entire species is only represented by a few founders that were able to be secured in *ex situ* prior to extirpation. The current status represents a significant decline in the species viability, which is only reflected in extremely low representation in *ex situ* living collections. See Table 4 below for the species viability summary.

Table 4. Species viability summary for *Ranunculus hawaiiensis*.

The 3Rs	Resiliency	Redundancy	Representation	Overall Viability
Current Condition	Extremely Low	Extremely Low	Extremely Low	Extremely Low

LITERATURE CITED

- Ball, D.L., S. Lowe, M.K. Reeves, F. Amidon, and S.E. Miller. 2020. Hawai'i: mesic grasslands and shrublands. Pages 923–947. In *Encyclopedia of the Worlds Biomes*. M.I. Goldstein and D.A. DellaSala (Eds.). Elsevier. <https://doi.org/10.1016/B978-0-12-409548-9.11963-3>.
- [BISH] Herbarium Pacificum Bishop Museum 2020. Herbarium specimen detail for *Ranunculus hawaiiensis*. (BISH1028531). <https://plants.jstor.org/stable/10.5555/al.ap.specimen.bish1028531> [accessed on 20 July 2020].
- [BISH] Herbarium Pacificum Bishop Museum (BISH). Herbarium specimen detail for *Ranunculus hawaiiensis*. (BISH1028534) <https://plants.jstor.org/stable/10.5555/al.ap.specimen.bish1028534> [accessed on 20 July 2020].
- [BISH] Herbarium Pacificum Bishop Museum (BISH). Herbarium specimen detail for *Ranunculus hawaiiensis*. (BISH1028539) <https://plants.jstor.org/stable/10.5555/al.ap.specimen.bish1028539> [accessed on 20 July 2020].
- [BISH] Herbarium Pacificum Bishop Museum (BISH). Herbarium specimen detail for *Ranunculus hawaiiensis*. (BISH1028540) <https://plants.jstor.org/stable/10.5555/al.ap.specimen.bish1028540> [accessed on 20 July 2020].
- Carlquist, S. 1966. The biota of long-distance dispersal. III. Loss of dispersibility in the Hawaiian flora. *Brittonia* 18(4): 310–335.
- Clark, M., M.K. Reeves, F. Amidon, and S.E. Miller. 2020. Hawaiian Islands wet forests. In *Encyclopedia of the Worlds Biomes*, M.I. Goldstein and D.A. DellaSala (Eds.), Elsevier. Pp. 328–345. <https://doi.org/10.1016/B978-0-12-409548-9.11920-7>.
- Duncan T, G. 1999. Ranunculaceae. In *Manual of the Flowering Plants of Hawaii*, Wagner, W.L., D.R. Herbst, and S.H. Sohmer (eds.), University of Hawai'i Press and Bishop Museum Press, Honolulu. P. 1,088.
- Fortini, L, J. Price, J. Jacobi, A. Vorsino, J. Burgett, K. Brinck, F. Amidon, S. Miller, S. Gon III, G. Koob, and E. Paxton. 2013. A landscape-based assessment of climate change vulnerability for all native Hawaiian plants. Technical Report HCSU-044, Hawai'i Cooperative Studies Unit, University of Hawai'i at Hilo, Hilo. 134 pp.
- Gagne W.C. and L.W Cuddihy. 1999. Vegetation. In *Manual of the Flowering Plants of Hawaii*, Wagner, W.L., D.R. Herbst, and S.H. Sohmer (eds.), University of Hawai'i Press and Bishop Museum Press, Honolulu. Pp. 93–114.

- [Hakalau NWR] Hakalau National Wildlife Refuge. 2019. Endangered Species Report, Endangered and Threatened Plants, Nēnē and forest birds, (Permit No. TE09050-8, Sub-permit No. HFNWR-8). 11 pp.
- [HBMP] Hawai‘i Biodiversity and Mapping Program (HBMP). 2010. Database records for *Ranunculus hawaiiensis*. University of Hawai‘i at Manoa, Honolulu, Hawai‘i.
- [HAWP] Hawai‘i Association of Watershed Partnerships. 2020. Watershed Partnerships. Retrieved from: <http://hawp.org/>. [Accessed on 27 August 2020].
- [HAVO] Hawai‘i Volcanoes National Park. 2003. Report on controlled propagation of listed and candidate species, as designated under the U.S. Endangered Species Act. Unpublished report submitted to the U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, Hawai‘i.
- [HAVO] 2019. Annual Report the U.S. Fish and Wildlife Service Threatened and Endangered Plants HAVO Permit TE-018078-21. 33 pp.
- [HDLNR] Hawaii Department of Land and Natural Resources. 2015. State of Hawai‘i Department of Land and Natural Resources, Division of Forestry and Wildlife Title 13 Chapter 123 Rules Regulating Game Mammal Hunting. <https://dlnr.hawaii.gov/dofaw/files/2013/09/HAR-123-Game-Mammals.pdf>. 78 pp.
- [HDOA] Hawaii Department of Agriculture. 2009. Plant guidelines for importation to Hawaii. Available online at <http://hawaii.gov/hdoa/pi/pq/plants>.
- [HPPRCC] Hawai‘i and Pacific Plants Recovery Coordinating Committee. 2011. Revised recovery objective guidelines. 8 pp.
- [IUCN] International Union for Conservation of Nature. 2013. IUCN Guidelines for Reintroductions and Other Conservation Translocations. Version 1.0. Gland, Switzerland: IUCN Species Survival Commission, viiii + 57 pp.
- Javar-Salas, C., R. Pe‘a, F. Amidon, M.K. Reeves, and S.E. Miller. 2020. Hawaiian Islands dry forest. In Encyclopedia of the Worlds Biomes, M. I. Goldstein and D. A. DellaSala (Eds.), Elsevier. Pp. 295–327. <https://doi.org/10.1016/B978-0-12-409548-9.11890-1>.
- Lilleeng-Rosenberger, K. 2005. Growing Hawai‘i’s Native Plants: A Simple Step-by-Step Approach for Every Species. Mutual Publishing. 416 pp..
- Lowe, S., D.L. Ball, M.K. Reeves, F. Amidon, and S.E. Miller. 2020. Hawai‘i mesic forests. In Encyclopedia of the Worlds Biomes, M.I. Goldstein and D.A. DellaSala (eds.), Elsevier. Pp. 346–372. <https://doi.org/10.1016/B978-0-12-409548-9.11930-X>.

- Lyon Arboretum. 2019. Lyon Arboretum Hawaiian Rare Plant Program. Report on controlled propagation of listed and candidate species, as designated under the U.S. Endangered Species Act. Unpublished report submitted to the U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, Hawai'i.
- Mann, H. 1866. Five Hundred and Seventy-First Meeting. September 11, 1866. Monthly Meeting; Enumeration of Hawaiian Plants. Proceedings of the American Academy of Arts and Sciences 7 (May, 1865–May, 1868), Pp. 135–235.
- National Tropical Botanical Garden. 2002. Report on controlled propagation of listed and candidate species, as designated under the U.S. Endangered Species Act. Unpublished report submitted to the U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, Hawai'i.
- Pe'a, R., C. Javar-Salas, M.K. Reeves, F. Amidon, and S.E. Miller. 2020. Hawai'i dry grasslands and shrublands. In Encyclopedia of the World's Biomes, M.I. Goldstein and D.A. DellaSala (eds.), Elsevier. Pp. 880–899. <https://doi.org/10.1016/B978-0-12-409548-9.11961-X>.
- [PEPP] Plant Extinction Prevention Program. 2017. Plant Extinction Prevention Program, FY 2017 Annual Report (Oct 1, 2016–Sep 30, 2017). US FWS CFDA program #15.657; Endangered species conservation-recovery implementation funds, Cooperative Agreement: F14AC00174, December 31, 2017, UH Manoa, Pacific Cooperative Studies Unit. 235 pp.
- [PEPP] Plant Extinction Prevention Program. 2019. Plant Extinction Prevention Program, FY 2019 Annual Report (Oct 1, 2018–Sep 30, 2019), US FWS CFDA program #15.657; Endangered species conservation-recovery implementation funds, Cooperative Agreement F18AC00502 & F14AC00174, December 31, 2019, UH Manoa, Pacific Cooperative Studies Unit. 53 pp.
- Pratt L.W., T.K. Pratt, and D. Foote. 2007. Technical Report HCSU-025 Rare and Endangered Species of Hawai'i Volcanoes National Park, Endangered, Threatened, and Rare Animal, Plant, and Community Handbook. Hawai'i Cooperative Studies Unit. University of Hawai'i at Hilo. 271 pp.
- Rock, J.F. 1911. The Indigenous Trees of the Hawaiian Islands. Pacific Tropical Botanical Garden. 1974. 548 pp.
- Sakai, A., W. Wagner, D. Ferguson, and D. Herbst. 1995. Origins of dioecy in the Hawaiian flora. Ecology 76(8): 2517–2529.
- [TMA] Three Mountain Alliance 2007. Three Mountain Alliance Watershed Management Plan. 82 pp.

[TNCH] The Nature Conservancy Hawai‘i. 2011. Waikamoi Preserve, Long Range Management Plan. 46 pp.

[USFWS] U.S. Fish and Wildlife Service. 2016. USFWS Species Status Assessment Framework. Version 3.4 dated August 2016.

[USFWS] 2020. U.S. Fish and Wildlife Service. Unpublished GIS data. Pacific Islands Fish and Wildlife Office, Honolulu, Hawai‘i.

[VRPF] Volcano Rare Plant Facility. 2002–2019. Report on controlled propagation of listed and candidate species, as designated under the U.S. Endangered Species Act. Unpublished report submitted to the U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, Hawai‘i.

Wagner, W.L., D.R. Herbst, and D.H. Lorence. 2005. Flora of the Hawaiian Islands. <http://botany.si.edu/pacificislandbiodiversity/hawaiianflora/index.htm>. [accessed 20 July 2020].

Personal Communication

PEPP. *Ranunculus* at Hakalau. Email to Michelle Clark, Pacific Islands Fish and Wildlife Office, 21 August 2020.

Fay, K. *Ranunculus mauiensis* and *R. hawaiiensis* in Waikamoi. Email to Michelle Clark, Pacific Islands Fish and Wildlife Office, 1 June 2020.